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EVALUATION OF THE PSYCHOMETRIC PROPERTIES OF INSTRUMENTS FOR ASSESSING UNIVERSITY STUDENTS' ANALYTICAL THINKING SKILLS IN ZOOLOGY COURSE

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Abstract. *The need for an explicit and validated instrument to assess analytical thinking skills in Zoology courses presents a critical divide in educational assessment. The research aims to evaluate the psychometrics of the instrument for assessing students' analytical thinking skills in the Zoology course. The main problem identified is the lack of an instrument that explicitly assesses analytical thinking skills in the context of Zoology and limitations in construct validity and measurement reliability. Data were collected from 642 students from various universities using stratified random sampling. The psychometric evaluation includes descriptive analysis, content validity with Aiken's V, construct validity through Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA), and internal reliability with Cronbach's Alpha and Composite Reliability (CR). The results indicate that the instrument has good validity and reliability. Cronbach's Alpha and CR values are more than .70, indicating high internal consistency. Discriminant validity with an Average Variance Extracted (AVE) value above .50 confirms the differences between factors. Furthermore, exploratory factor analysis identifies five factors that align with the Marzano model. Demographic factors such as age, Grade Point Average (GPA), university, involvement in extracurricular activities, and international experience significantly affect students' analytical thinking skills. The research's implications extend to the development of more accurate instruments for measuring analytical thinking skills in higher education and to providing new insights into the factors that contribute to the development of students' thinking skills.*
Keywords: *analytical thinking skills, construct validity, higher education, psychometric evaluation*

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Introduction

The skill of analytical thinking is an essential cognitive aspect in the study of Zoology in higher education, as it enables students to understand the complex connection between the structure, function, and evolution of living organisms. Analytical thinking skills are necessary because Zoology not only focuses on memorizing concepts but also on analyzing the biological and ecological mechanisms that support life (Macpherson, 2012; Pflüger, 2017). Previous research has suggested that analytical thinking skills are positively correlated with conceptual understanding in the biological sciences (Kao, 2016). Moreover, studies have revealed that students who develop analytical thinking skills are better able to interpret data and construct evidence-based arguments (Ayyildiz & Yilmaz, 2021; Kwangmuang et al., 2021). Students are often faced with tasks that require the ability to distinguish, classify, and evaluate scientific information from various sources, such as animal morphology, physiology, and ecology data.

A number of instruments have often focused more on general cognitive aspects without specifically evaluating analytical skills, such as the ability to compare, classify, or evaluate scientific information systematically (Han & Abdrahim, 2023; Soh et al., 2012). The need for the development of measurement tools is indicated by the lack of instruments specifically designed to measure analytical thinking skills in science education. Previous studies have suggested that most existing analytical thinking tests still focus on the generalization of cognitive skills without considering the characteristics of specific disciplines, such as science (McLaughlin & Bailey, 2023). Furthermore, research has confirmed that many evaluations in science education still use a traditional rote-based approach, thus underrepresenting the level of analysis performed by students (Amua-Sekyi, 2016; Hong & Song, 2020). However, there are challenges in developing instruments capable of measuring analytical thinking skills holistically, such as the need for empirical validation and

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limitations in the application of measurement models in line with modern cognitive theory (Zhang et al., 2020). Therefore, further research is needed to develop instruments that are not only conceptually valid but also widely applicable in science education to provide an overview of students' analytical thinking skills.

Although various instruments have been developed to measure analytical thinking skills, there are still major unresolved challenges, such as limitations in construct validity and reliability in various disciplinary contexts. Several studies have suggested that many of the instruments used to measure analytical thinking skills still rely on multiple-choice questions that are less able to capture complex cognitive processes in depth (Kwangmuang et al., 2021; Mešić et al., 2019). This challenge is important to consider because the measurement of analytical thinking skills must reflect how individuals organize, interpret, and evaluate information in real contexts. A study by Kao (2016) has emphasized that most analytical thinking instruments only measure general abilities without considering the specifics of different scientific domains. Furthermore, research has suggested that there are still gaps in the development of instruments that can accurately differentiate between different levels of analytical thinking ability based on the complexity of the cognitive tasks given (Kwangmuang et al., 2021; Kwinram et al., 2022). However, the development of more authentic and performance-based instruments faces obstacles in implementation, such as the need for a longer time in assessment and difficulties in scoring objectively (Scherer & Tiemann, 2014).

Research Focus

The research focuses on psychometric evaluation to assess students' analytical thinking skills in the Zoology course, which has not been widely developed in previous research. Studies have largely focused on the assessment of analytical thinking skills in the context of science education in general without considering the specific characteristics of the discipline of Zoology, such as the ability to classify species, analyze evolutionary, and evaluate ecological and physiological data of animals (Costello & Osborne, 2005; Monteiro et al., 2022; Shirali et al., 2016). The research focus is based on the need for more contextual and biology-based instruments to enhance the validity of analytical thinking skills assessment. A study by Lehtinen (2023) has suggested that analytical thinking assessment instruments in biology are limited and often use a general approach that does not reflect the complexity of bioscience. Moreover, research by Kwangmuang et al. (2021) has emphasized that the measurement of analytical thinking skills in science needs to consider an inquiry-based and problem-solving approach, which is more in line with the characteristics of learning in Zoology. However, there are challenges in developing instruments that reflect students' analytical thinking processes, especially in terms of empirical validation and its application on a wider scale (Kao, 2016; Marletaz, 2019).

The exploration of the factor structure of analytical thinking skills in the context of Zoology is needed to ensure that the assessment of cognitive dimensions is appropriate to the characteristics of the discipline. The importance of factor structure exploration is based on the principle that each discipline has unique analytical thinking characteristics, which reflect how students process, interpret, and evaluate information in specific contexts (Atesgoz & Sak, 2021; Derakhshan et al., 2023). A study by Marzano (2001) has suggested that analytical thinking consists of various specific skills, such as matching, classifying, error analysis, generalizing, and specifying, which can contribute to conceptual understanding in science. Furthermore, research by Atesgoz and Sak (2021) and Gao et al. (2023) has emphasized that in the field of biology, the factor structure of analytical thinking must be studied in more depth because learning biology requires classification skills and scientific evidence-based problem-solving. However, the exploration of the factor structure of analytical thinking skills in Zoology faces challenges, such as differences in students' level of understanding of the concept of Zoology and variability in the teaching approaches used in various higher education institutions (Costello & Osborne, 2005; Monteiro et al., 2022; Shirali et al., 2016). Therefore, further research is needed to ensure that the measurement of analytical thinking skills in Zoology is not only theoretically valid but also able to describe students' cognitive abilities more accurately and contextually (Colon-Berlingeri & Burrowes, 2011).

Demographic factors, such as gender, age, level of education, socioeconomic background, and academic experience, influence analytical thinking skills and are a relevant issue in science education. Previous studies have found variations in the level of analytical thinking based on certain demographic characteristics; for example, students with international experience or involvement in additional academic activities have tended to demonstrate better analytical skills compared to those with limited exposure to diverse learning experiences (Basaran & Berberoglu, 2012; Kim et al., 2025). The relevance of the issue of demographic factors is based on the finding that analytical thinking skills do not only depend on internal cognitive factors but are also influenced by the social environment

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and learning experiences that individuals acquire (Salvati et al., 2019). A study by Liu and Pásztor (2023) has suggested that diverse academic experiences and social interactions can improve analytical thinking skills through exposure to different perspectives. Moreover, research by Zuhroh et al. (2025) has found that students with higher socioeconomic backgrounds have had wider access to learning resources that can support the development of analytical thinking skills. However, there are arguments that the influence of demographic factors is not always significant because analytical thinking skills can depend more on learning strategies and teaching methods applied in the science curriculum (AL-Qadri et al., 2025). Therefore, further research is needed to understand how demographic factors interact with other educational variables in influencing analytical thinking skills so that it can be used as a basis for designing more inclusive and effective interventions in science education.

Research Aim and Research Questions

The current research aimed to evaluate the assessment instruments for analyzing thinking skills in Zoology courses that had validity and reliability. The problems identified previously indicated that the instruments available did not specifically assess analytical thinking skills in the context of the Zoology discipline, and there were still limitations in the construct validity and reliability of the measurements. The research contributed to the development of a more valid and reliable analytical thinking skills assessment instrument by applying a psychometric evaluation approach that included content validity, construct validity, criterion validity, and internal reliability. Problems in previous research indicated that many of the instruments used to measure analytical thinking skills did not fully meet psychometric standards, so the measurement results were often inconsistent and did not reflect analytical thinking abilities. Research questions: (1) How valid and reliable was the instrument in measuring analytical thinking skills in the Zoology course? (2) What was the factor structure of the developed instrument in measuring analytical thinking skills in Zoology students based on exploratory and confirmatory factor analysis?; (3) How did demographic factors affect students' analytical thinking skills?

Research Methodology

General Background

The psychometric evaluation of the instrument for assessing students' analytical thinking skills in the Zoology course was based on a methodological approach to ensure the validity and reliability of the measuring instrument. The process began with the design of analytical thinking skills indicators adapted from Marzano (2001), covering the aspects of matching, classifying, error analysis, generalizing, and specifying. The indicators were developed through a literature review and adjustments to the characteristics of zoology material to ensure conceptual and contextual relevance. The psychometric evaluation of the instrument was carried out through a series of statistical analyses aimed at testing the quality and feasibility of the instrument items. Descriptive analysis was used to explore data distribution and detect possible bias in response distribution. The validity test involved content validity, which was confirmed through expert judgment using Aiken (1980); discriminant validity to ensure that the instrument was able to distinguish between different constructs; and criterion validity. The psychometric evaluation aimed to ensure that the developed instrument could be used consistently in various measurement contexts.

Participants

The study participants were students enrolled in Zoology courses at various universities. The total population consisted of 1242 students, and a census approach was used, meaning the entire population was included in the initial sample. This method ensured comprehensive data collection and eliminated potential sampling bias. The stratified random sampling technique was applied to organize students based on their university, ensuring representation from each institution. Within each university, students were further stratified based on educational level (3rd, 5th, and 7th semester) and Grade Point Average (GPA) category to maintain proportional sample composition. After data cleaning and handling of incomplete responses, 642 students were included in the final analysis. The demographic distribution of participants is presented in Table 1.

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Table 1
Demographic Characteristics of Respondents

Demographic	Sub-demographic	*N*	%
Gender	Male	203	31.62
	Female	439	68.38
Age	17 – 19 years	216	33.64
	20 – 22 years	239	37.23
	23 – 25 years	187	29.13
University	University 1	81	12.62
	University 2	81	12.62
	University 3	79	12.31
	University 4	78	12.15
	University 5	80	12.46
	University 6	79	12.31
	University 7	83	12.93
	University 8	81	12.62
Grade Point Average (GPA)	2.6 – 2.8	112	17.45
	2.9 – 3.1	120	18.69
	3.2 – 3.4	161	25.08
	3.5 – 3.7	140	21.81
	3.8 – 4.0	109	16.98
Level of Education	3rd semester students	205	31.93
	5th semester student	216	33.64
	7th semester student	221	34.42
Socioeconomic Background	Low socioeconomic status	39	6.07
	High socioeconomic status	603	93.93
Involvement in Extracurricular Activities	Active	266	41.43
	Inactive	376	58.57
International Experience	Has experience studying abroad	22	3.43
	Only studying domestically	620	96.57

Demographic characteristics provided insight into the diversity of participants' backgrounds that could influence research results, especially in evaluating students' analytical thinking skills in the Zoology course. Factors such as level of education, GPA, and involvement in extracurricular activities had the potential to contribute to variations in analytical thinking abilities, so they were taken into consideration in the data analysis. A sample of zoology students from several universities was selected to ensure that the research was more generalized and reflected the diversity of academic and demographic backgrounds.

Measures

The research instrument was developed using a theoretical approach to ensure its validity and reliability in assessing students' analytical thinking skills in the Zoology course. The instrument was constructed based on the theory of analytical thinking skills adapted from Marzano (2001), which included five indicators: matching, classifying, error analysis, generalizing, and specifying. Matching was operationalized through questions that required students to identify the similarities or differences in the anatomical, physiological, or behavioral characteristics of various animal groups based on concepts that had been studied. Classifying was developed in the form of a classification task, in which students were required to group species or biological structures based on certain criteria,

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such as phylogeny. The error analysis indicator was measured through questions that presented cases or experimental results containing errors, requiring students to identify these errors and provide scientific justifications for necessary corrections. Generalizing was operationalized by asking students to conclude patterns or principles found in various biological phenomena. The specifying indicator was evaluated through questions that required students to apply general principles to specific situations, for example, by explaining how changes in a particular environment could affect the structure and function of organisms in an ecosystem.

Procedure

The process of data collection in the research was conducted through the administration of instruments distributed to students enrolled in Zoology courses at various universities that were included in the research sample. Data collection was carried out under controlled conditions in the classroom during the agreed time, ensuring that students had enough time to complete the instrument fully and without interruption. Each student was given instructions on how to answer the questions, and the purpose of measuring analytical thinking skills was explained to minimize bias in responses. Data was collected during active lectures, when students were familiar with the Zoology material being tested. Prior to data collection, a small-scale trial of the instrument was conducted to ensure administrative feasibility and student readiness to complete the questions. After the instrument was distributed, participants were asked to answer the questions independently within the allotted time, without assistance from instructors or peers, to ensure that the collected data reflected individual analytical thinking abilities. Data collection was conducted with due regard for research ethics, where each participant was informed about the purpose of the research, and their consent to participate (informed consent) was obtained before completing the instrument. Participants were assured of confidentiality, and their responses were used solely for research purposes.

Exploratory Factor Analysis (EFA)

EFA was utilized to identify the factor structure underlying the analytical thinking skills measured by the instrument. EFA was conducted to explore and confirm whether the indicators in the instrument actually measured the intended dimensions of analytical thinking skills, which referred to categories such as matching, classifying, error analysis, generalizing, and specifying, according to Marzano (2001). For factor extraction, the criterion used was eigenvalue more than 1, which was a common approach in EFA to determine the number of extracted factors (Field, 2024). For factor rotation, Varimax rotation, an orthogonal rotation, was applied (Field, 2024).

Confirmatory Factor Analysis (CFA)

CFA was conducted to confirm the factor structure discovered through EFA. CFA was used to verify construct validity by testing whether the data obtained in the study were consistent with the hypothesized factor model based on the EFA results. The model fit indicators included Chi-Square (χ^2) (Hu & Bentler, 1999), Goodness-of-Fit Index (GFI > .90) (Doll et al., 1994), Root Mean Square Error of Approximation (RMSEA < .08) (Ng et al., 2024), and Comparative Fit Index (CFI > .90) (Ferrando et al., 2024).

Internal Consistency

The internal reliability of the instrument was measured using Cronbach's Alpha, which was one of the most commonly used measures to assess the internal consistency of an instrument. The alpha value was considered good if it was greater than .70, although in some cases, higher values, such as .80 or .90, indicated excellent reliability. Internal reliability was measured for each of the factors identified in the CFA. Each factor resulting from the CFA model was tested by calculating Cronbach's Alpha to ensure that each dimension of analytical thinking skills measured had sufficient internal consistency.

Instrument Validity

The instrument's validity was evaluated through content validity, discriminant validity, and criterion validity. Content validity was assessed using Aiken's V method, which involved seven experts in the fields of education and psychometrics. Discriminant validity was tested using two main approaches: the Fornell-Larcker Criterion and the

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Heterotrait-Monotrait Ratio (HTMT). As for criterion validity, the evaluation was conducted through regression analysis. The criterion validity was tested by examining whether the instrument scores could predict the criterion variable.

Demographic Analysis

Analysis of Variance (ANOVA) was used to identify whether there were significant differences in analytical thinking skills based on demographic factors, such as gender, GPA, level of education, socioeconomic background, involvement in extracurricular activities, and international experience. Each demographic factor was considered as an independent variable that could influence the analytical thinking skills score, which was measured using the developed instrument. The most influential factors on students' analytical thinking skills were determined through ANOVA, which tested for significant differences between groups based on various demographic factors. The results indicate the elements that influence the development of students' analytical thinking skills in the context of Biology education.

Research Results

Descriptive Results

The results of the descriptive analysis revealed variations in analytical thinking skills based on demographic factors. Table 2 presents the differences in scores across these factors. By gender, men scored higher in matching (76.02) than women (70.43), while women performed better in classifying (81.96 vs. 71.24) and error analysis (71.96 vs. 61.24). Regarding age, the 23–25 age group achieved the highest scores in classifying (78.03) and error analysis (68.03), while the 17–19 age group excelled in generalizing (70.25).

Table 2
Descriptive Statistics of Analytical Thinking Skills

Demographic	Matching		Classifying		Error analysis		Generalizing		Specifying	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Gender										
Male (*N* = 203)	76.02	9.74	71.24	14.51	61.24	14.51	67.16	9.11	74.70	9.71
Female (*N* = 439)	70.43	10.73	81.96	10.99	71.96	10.99	76.21	9.08	78.09	8.98
Age										
17 – 19 years (*N* = 216)	73.86	10.92	64.68	6.56	54.68	6.56	70.25	6.87	75.08	10.80
20 – 22 years (*N* = 239)	71.31	9.53	61.74	13.66	51.74	13.66	63.16	9.19	76.50	9.83
23 – 25 years (*N* = 187)	70.72	10.34	78.03	12.08	68.03	12.08	63.07	5.32	78.72	8.91
University										
University 1 (*N* = 81)	71.30	10.22	60.62	14.70	50.62	14.70	71.30	6.77	76.73	9.54
University 2 (*N* = 81)	75.13	9.51	84.97	7.12	74.97	7.12	71.45	8.93	77.28	9.53
University 3 (*N* = 79)	70.83	9.42	65.45	6.83	55.45	6.83	75.04	9.57	75.32	9.43
University 4 (*N* = 78)	79.83	10.90	69.13	10.25	59.13	10.25	68.74	7.63	74.96	9.97
University 5 (*N* = 80)	76.78	9.03	72.96	7.91	62.96	7.91	77.58	6.37	76.40	9.33
University 6 (*N* = 79)	73.57	8.62	78.36	6.39	68.36	6.39	78.59	8.46	75.01	7.68
University 7 (*N* = 83)	74.80	10.11	68.76	8.66	58.76	8.66	78.78	6.03	76.24	9.80
University 8 (*N* = 81)	69.81	8.97	73.68	12.85	63.68	12.85	67.34	8.12	75.13	7.35
GPA										
2.6 – 2.8 (*N* =112)	80.51	10.28	65.99	10.14	55.99	10.14	78.78	5.73	72.35	10.11
2.9 – 3.1 (*N* =120)	69.48	9.95	77.77	5.46	67.77	5.46	75.69	9.00	74.21	9.80

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Demographic	Matching		Classifying		Error analysis		Generalizing		Specifying	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
3.2 – 3.4 (*N* =161)	80.09	9.78	78.23	6.71	68.23	6.71	61.99	6.24	77.24	9.20
3.5 – 3.7 (*N* =140)	72.86	9.38	61.95	14.49	51.95	14.49	70.86	6.47	78.90	8.40
3.8 – 4.0 (*N* =109)	71.49	10.27	88.97	13.08	78.97	13.08	69.03	5.50	81.48	6.03
Level of Education										
3rd semester students (*N* = 205)	73.42	10.94	69.14	5.98	59.14	5.98	79.58	4.83	73.83	12.37
5th semester student (*N* = 216)	79.85	9.87	80.53	9.40	70.53	9.40	62.57	8.77	76.41	9.89
7th semester student (*N* = 221)	75.93	8.92	63.66	9.95	53.66	9.95	67.14	9.09	79.39	8.89
Socioeconomic Background										
Low socioeconomic status (*N* = 39)	72.58	9.20	61.03	14.09	51.03	14.09	62.30	4.75	66.86	13.84
High socioeconomic status (*N* = 603)	71.10	9.80	67.76	11.63	57.76	11.63	70.84	7.04	77.81	9.43
Involvement in Extracurricular Activities										
Active (*N* = 266)	70.43	10.01	69.35	10.20	59.35	10.20	69.85	6.87	79.69	8.91
Inactive (*N* = 376)	69.91	10.30	76.40	6.85	66.40	6.85	67.32	9.30	75.31	9.39
International Experience										
Has experience studying abroad (*N* = 22)	77.36	7.95	89.09	12.75	79.09	12.75	77.46	8.55	80.77	5.51
Only studying domestically (*N* = 620)	71.41	9.72	88.18	13.95	78.18	13.95	60.58	6.84	75.99	8.57

Exploratory Factor Analysis

The factor analysis results indicated that the data used was well suited for factor analysis, with a Kaiser-Meyer-Olkin (KMO) value of 0.812 and a significant Bartlett's Test of Sphericity result ($\chi^2(190) = 1324.56$; $p < .01$). Accordingly, there was a sufficient correlation between the variables, allowing factor analysis to be properly conducted. Based on Kaiser's criterion, five main factors with eigenvalues more than 1 explained 75.33% of the total variance in the data. Table 3 presents the rotated component matrix with Varimax rotation, which reveals that all items have factor loadings (> .70) on the expected factors.

The first factor (matching) included items related to the ability to recognize similarities and differences in attributes (Items 1-4). The second factor (classifying) involved the ability to group items into appropriate categories (Items 5-8). The third factor (error analysis) related to the ability to assess errors in reasoning and procedural validity (Items 9-12). The fourth factor (generalizing) reflected the ability to identify patterns and build new generalizations (Items 13-16). The fifth factor (specifying) related to the application of generalizations or principles in a particular situation (Items 17-20).

Table 3
Exploratory Factor Analysis of Analytical Thinking Skills: Factor Loadings of Each Item

Item	Description	Factor Loadings				
		1	2	3	4	5
1	Determine attribute similarities	.78				
2	Determine attribute differences	.75				
3	Determine differences in attributes or characteristics of items to be matched for analysis.	.74				
4	Determine similarities in attributes or characteristics of items to be matched for analysis.	.76				
5	Determine the characteristics of items to be classified		.83			
6	Group items based on category similarity		.83			
7	Group items based on category differences		.82			

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Item	Description	Factor Loadings				
		1	2	3	4	5
8	Associate relationships between items		.81			
9	Identify any errors in the reasoning presented			.84		
10	Check the impact of each aspect of the procedure			.85		
11	Assess the validity of knowledge based on explicit criteria			.85		
12	Apply and interpret procedures correctly. Apply and interpret procedures correctly			.85		
13	Determine patterns based on specific information or observations without making assumptions				.86	
14	Find patterns or relationships in information				.87	
15	Make general statements that explain these patterns or relationships				.88	
16	Build new generalizations or principles based on known or observed knowledge or information				.89	
17	Identify generalizations or principles that apply in certain situations.					.90
18	Determine the conclusions that can be drawn or predictions from a generalization.					.91
19	Produce/apply new applications of known generalizations or principles.					.92
20	Ensure that certain situations meet the conditions that must exist for the generalization or principle to be applied.					.92

Confirmatory Factor Analysis (CFA)

The CFA results shown in Table 4 indicate that the tested model was well-fitted with the data based on various model fit indices. The Chi-Square value relative to the degrees of freedom (χ^2/df) was 2.34, which fell within the accepted range (<3.00), indicating that the model had a good fit. Moreover, the RMSEA value was .045 and the SRMR value was .041, both below the .08 limit, suggesting that the model had a low level of residual error and was in accordance with the data.

Table 4
Model Fit Indices for Confirmatory Factor Analysis of Analytical Thinking Skills

Fit Index	Value	Cut-off Criteria	Interpretation
Chi-Square (χ^2/df)	2.34	< 3.00	Good Fit
RMSEA	.045	< .08	Good Fit
SRMR	.041	< .08	Good Fit
CFI	.956	> .90	Good Fit
TLI	.943	> .90	Good Fit
NFI	.925	> .90	Good Fit
GFI	.931	> .90	Good Fit
AGFI	.905	> .90	Good Fit

Internal Consistency

The results of the reliability analysis showed that all factors in the model had good internal consistency. Table 5 presents the composite reliability (CR) values for each factor, which ranged from .855 to .876, exceeding the minimum limit of .70. This indicated that each factor had a high level of reliability. Furthermore, Cronbach's Alpha (α) values ranged from .821 to .847, also exceeding the .70 threshold, suggesting that each factor had good internal consistency and was reliable for measuring the analytical thinking skill construct.

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Table 5
Internal Consistency Reliability of Analytical Thinking Skill Factors

Factor	Σ Standardized Loadings (∑λ)	$\Sigma\lambda^2$	$\Sigma(1-\lambda^2)$	CR	Cronbach's Alpha	Interpretation (CR > .70, α > .70)
Matching	3.232	2.571	.432	.855	.821	Reliable
Classifying	3.313	2.671	.382	.873	.843	Reliable
Error Analysis	3.294	2.652	.393	.871	.841	Reliable
Generalizing	3.302	2.662	.371	.876	.847	Reliable
Specifying	3.261	2.622	.401	.867	.838	Reliable

Content Validity

The results of the content validity analysis using Aiken's V showed that all items in the research instrument were valid. The Aiken's V value for each factor was above .75, which is the minimum threshold for adequate content validity. Furthermore, most factors had an Aiken's V value above .85, indicating a very strong level of content validity based on expert assessment. Overall, with all 20 essay questions demonstrating good content validity, this instrument was deemed feasible for use in research to measure analytical thinking skills in students in the Zoology course.

Discriminant Validity

The Average Variance Extracted (AVE) analysis results showed that all factors in the model had good convergent validity. The AVE value for each factor ranged from .643 to .671, all of which exceeded the minimum limit of .50. Specifically, the matching factor had an AVE of .643, classification had .671, error analysis had .662, generalization had .658, and specifying had .649. These findings indicated that the proportion of variance explained by the indicator in each factor was greater than the error variance, meaning that the construct measured accurately represented the intended concept. Discriminant validity was supported when the square root of the AVE for each factor was greater than the correlation between factors. The square root of AVE for each factor was matching (.801), classifying (.822), error analysis (.812), generalizing (.813), and specifying (.811). The results supported the idea that the constructs of matching, classifying, error analysis, generalizing, and specifying were dimensions of analytical thinking skills. Table 6 presents the HTMT values, which range from .601 to .702, indicating that no correlation is too high between the tested factors.

Table 6
Heterotrait-Monotrait (HTMT) Ratio of Correlations for Analytical Thinking Factors

Factor	Matching	Classifying	Error Analysis	Generalizing	Specifying
Matching	-	.651	.613	.603	.633
Classifying	.651	-	.683	.644	.702
Error Analysis	.612	.682	-	.625	.653
Generalizing	.601	.643	.622	-	.691
Specifying	.632	.703	.652	.693	-

Criterion Validity

Criterion validity was satisfied because most predictor variables had a significant ($p < .05$) with the indicator of analytical thinking skills. The results of the regression test on criterion validity showed that GPA had the strongest influence on all aspects of analytical thinking skills, with a beta value ranging from .28 to .35 and a high level of significance ($p < .01$). Table 7 presents these results, indicating that GPA has a notable impact on analytical thinking skills.

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Table 7
Regression Coefficients for Criterion Validity of Analytical Thinking Constructs

Demographic	Matching		Classifying		Error Analysis		Generalizing		Specifying	
	β	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*
Gender	.123	.021	.092	.051	.141	.011	.133	.015	.101	.039
Age	.082	.045	.121	.018	.101	.036	.093	.041	.072	.048
University	.151	.013	.102	.043	.182	.007	.163	.012	.132	.020
GPA	.322	.017	.301	.016	.353	.018	.333	.012	.281	.019
Level of Education	.101	.039	.082	.062	.124	.028	.112	.034	.091	.046
Socioeconomic Background	.181	.009	.141	.035	.206	.005	.191	.007	.152	.018
Involvement in Extracurricular Activities	.251	.002	.202	.006	.286	.002	.262	.003	.222	.009
International Experience	.222	.004	.171	.019	.246	.004	.211	.008	.191	.012

Other factors that also had a significant influence on most aspects of analytical thinking skills were involvement in extracurricular activities and international experience. Both factors showed a stronger influence on all aspects of analytical thinking skills (β = .171 to .286, p < .05), indicating that students who were active in extracurricular activities and had international experience tended to have higher analytical thinking skills. Furthermore, socioeconomic background also had a significant influence on analytical thinking skills, particularly in the aspects of error analysis (β = .206, p = .005) and generalizing (β = .191, p = .007). Several other factors, such as gender, age, university, and level of education, also had a significant influence but with smaller regression coefficients (β = .072 to .182, p < .05), indicating that although these factors contributed to analytical thinking skills, their impact was not as strong as GPA, extracurricular involvement, or international experience.

Demographic Analysis

The results of the ANOVA indicated that several demographic factors significantly influenced various aspects of analytical thinking skills, although the level of significance varied. Table 8 presents the results of the ANOVA. Overall, these results showed that GPA, involvement in extracurricular activities, and international experience were the factors that most influenced analytical thinking skills. Furthermore, age and level of education also contributed to the development of certain aspects of analytical thinking skills, while socioeconomic background and gender had a more limited influence.

The GPA factor had a significant influence on almost all aspects of analytical thinking skills, with a high F value and a significant p-value. Table 8 shows that the highest effect of GPA was observed in error analysis (F = 63.18, p = .015) and generalizing (F = 67.22, p = .002), suggesting that students with higher GPA tended to have better error analysis and generalization skills. Involvement in extracurricular activities also had a significant effect on all aspects of analytical thinking skills, especially on error analysis (F = 143.19, p = .007) and specifying (F = 44.74, p = .003). The international experience factor had a significant effect on matching (F = 17.72, p = .029), classifying (F = 41.23, p = .019), and specifying (F = 6.74, p = .004), suggesting that students with international experience were better at connecting concepts, classifying information, and making specifications in analytical thinking. The age factor had a significant effect on generalizing (F = 156.67, p = .004) and specifying (F = 8.94, p = .031), demonstrating that older students tended to have better abilities in generalizing and determining specifications in analytical thinking. Meanwhile, socioeconomic background only showed a significant effect on matching (F = 5.76, p = .015) but not on other aspects of thinking skills. The level of education factor significantly influenced error analysis (F = 125.01, p = .004), generalizing (F = 37.22, p = .041), and specifying (F = 22.24, p = .005), but not matching and classifying. The gender factor had a significant effect on matching (F = 41.41, p = .024) and classifying (F = 29.22, p = .008), indicating that there were differences in analysis skills based on gender in these two aspects. However, the level of education factor did not show a significant effect on the aspects of error analysis, generalizing, and specifying.

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Table 8

Comparative Analysis of Analytical Thinking Factors Based on Demographic

Demographic	Matching		Classifying		Error analysis		Generalizing		Specifying	
	F	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Gender	41.412	.024	29.221	.008	.522	.340	.372	.837	.942	.790
Age	7.151	.008	0.131	.871	.722	.642	156.672	.004	8.942	.031
University	11.631	.005	4.611	.015	1.211	.572	.812	.833	6.751	.007
GPA	34.521	.004	3.571	.005	63.182	.015	67.222	.002	2.061	.001
Level of Education	0.261	.982	0.511	.925	125.012	.004	37.221	.041	22.241	.005
Socioeconomic Background	5.761	.015	1.301	.321	1.561	.772	.121	.833	.452	.976
Involvement in Extracurricular Activities	23.371	.019	39.122	.012	143.192	.007	34.641	.007	44.742	.003
International Experience	17.721	.029	41.232	.019	.891	.577	.642	.322	6.741	.004

Discussion

Validity and Reliability of Instruments in Measuring Analytical Thinking Skills

The results of the validity and reliability tests indicated that the instrument was reliable in measuring students' analytical thinking skills in the Zoology course. Furthermore, based on the results of internal consistency testing, all factors (matching, classifying, error analysis, generalizing, specifying) had a Cronbach's Alpha value greater than .70, which suggests that the instrument is reliable. The CR value is also greater than .70 for all factors, indicating good internal consistency in accordance with the criteria accepted in psychometric research. The results of discriminant validity suggested that all factors showed an AVE value of more than .50 and met the validity criteria applicable to construct measurement. Construct validity indicates valid results and no significant overlap between factors, which suggests that each factor measures a different aspect of analytical thinking skills. Moreover, the results of content validity, which showed an Aiken's V value of more than .80 on all factors, indicate that the instrument has good content validity.

The research findings suggested that the instrument developed to measure students' analytical thinking skills in the Zoology course had higher validity and reliability compared to previous instruments in the field of science. The instrument used to measure analytical thinking skills in previous research often demonstrated lower reliability values, even less than .70 on some factors, which indicated a lack of consistency in measurement results (Affandy et al., 2021). The results of research by Affandy et al. (2024) suggested that instruments with a Cronbach's Alpha lower than .70 often produced unstable results, especially in the context of measuring high-level thinking skills.

Furthermore, the discriminant validity of this instrument shows better results than the previous instrument, with an AVE value higher than .50, which ensures that each indicator measures different but clearly related constructs. This differs from the previous instrument, which showed higher construct overlap, potentially confusing the measurement of analytical thinking skills more specifically. However, although the instrument shows improvement in terms of validity and reliability, variations in the higher education context, such as differences in curriculum or teaching style, may affect measurement results (Salvati et al., 2019). Therefore, these findings contribute to the development of more accurate and reliable instruments for measuring analytical thinking skills, although further adaptation in a broader context is still needed.

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Factor Structure of the Analytical Thinking Skills Instrument

Based on the EFA results, five factors were identified that reflected the main dimensions of analytical thinking skills outlined by Marzano (2001) in his model, which also emphasized the skills of comparing, classifying, analyzing errors, generalizing, and specifying based on analytical reasoning. The KMO value was .812, which indicated that the data were good enough for factor analysis, and the results of Bartlett's Test of Sphericity showed a correlation between variables that supported the identified factor structure. Various studies supported the application of a five-factor structure to measure analytical thinking skills, such as research by Derakhshan et al. (2023); Sherrieb et al. (2012), which showed consistency in various higher education contexts, especially in the field of science. All items in each factor indicated factor loadings of more than .70, which confirmed that the indicator items had a high connection with each identified factor and showed consistency in the measurement of analytical thinking skills.

Although the factor structure fits very well with the concept of Marzano (2001) variations in the cultural context or educational curriculum can affect the validity and relevance of these factors. Furthermore, several other dimensions in measuring analytical thinking skills have not been covered in the five factors (Coubergs et al., 2017; Gao et al., 2023). Nevertheless, the CFA results show excellent goodness-of-fit indices (such as CFI = .956, RMSEA = .045, and SRMR = .041), reinforcing the conclusion that the factor structure found in the EFA is a good and reliable model for measuring analytical thinking skills at the higher education level.

The Influence of Demographic Factors on Students' Analytical Thinking Skills

The factors that had a significant influence were gender, age, university, GPA, level of education, involvement in extracurricular activities, and international experience. The data indicated that age, GPA, university, level of education, involvement in extracurricular activities, and international experience showed significant values in several dimensions of analytical thinking skills. For example, age had a significant influence on the dimensions of generalizing ($p = .004$) and specifying ($p = .031$). At the same time, GPA showed a significant influence on almost all dimensions of analytical thinking skills, especially matching ($p = .004$), classifying ($p = .005$), error analysis ($p = .015$), generalizing ($p = .002$), and specifying ($p = .001$). Involvement in extracurricular activities and international experience also exhibited significant effects, which strengthened the argument that these factors played a role in the development of students' analytical thinking skills (AL-Qadri et al., 2025; Liu & Pásztor, 2023). Factors such as age and GPA reflect cognitive and academic development that is directly related to analytical thinking skills. Previous research, such as that conducted by Yang and Arhonditsis (2022), has shown that older age is often associated with broader life experience and the ability to make better generalizations and specifications.

Meanwhile, GPA reflects academic achievement that indicates cognitive capacity and a deeper understanding in science courses (Basaran and Berberoglu, 2012; Kim et al., 2025). The results of a study conducted by Liu and Pásztor (2023) showed that involvement in extracurricular activities enhanced students' analytical thinking skills because these activities encouraged the development of better problem-solving and decision-making skills. In addition, international experience, which was related to exposure to diverse cultures and education systems, enriched students' analytical thinking skills in a broader global context (Salvati et al., 2019). The influence of gender demonstrated insignificant results in several dimensions of analytical thinking skills, such as error analysis and generalizing (Asturias et al., 2021). This could be due to cultural or social factors that were not controlled in the study, which may have affected how analytical thinking skills were developed or measured in certain groups of students. However, overall, factors such as age, GPA, level of education, involvement in extracurricular activities, and international experience contribute to shaping students' analytical thinking skills.

The data obtained indicate that students with a higher socioeconomic background demonstrate better analytical thinking skills, especially in the dimensions of matching and generalizing. Moreover, students with international experience show better results in specifying and classifying dimensions, analyzing information more deeply, and formulating more appropriate solutions based on cross-cultural experiences and different education systems. Research by Sauliune et al. (2014) suggested that students from higher socioeconomic backgrounds often had greater access to academic resources, which enriched their learning experience and supported the development of analytical thinking skills. Furthermore, international experience introduced students to different ways of thinking and new challenges, which could have enriched their analytical thinking skills. Research by Kim and

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Agrusa (2011) suggested that international experience improved students' analytical abilities as they learned to solve problems in more complex and diverse contexts. Similarly, Liu and Pásztor (2023) found that students with greater access to learning resources, which was often associated with a better socioeconomic background, had sharper thinking skills and higher analytical abilities. Research by Zuhroh et al. (2025) also found that international experience helped students become more adaptive and creative in problem-solving, which was a component of analytical thinking skills.

The data indicate that students with higher socioeconomic backgrounds and international experience demonstrate better analytical thinking skills. Furthermore, involvement in extracurricular activities also contributes to the improvement of analytical thinking skills. For example, students who engage in activities that challenge critical and analytical thinking, such as debates or research, tend to be more skilled in error analysis and generalization. Therefore, the higher education curriculum should provide opportunities for students to access various resources, international experiences, and extracurricular activities that enhance analytical thinking skills. Research by Zuhroh et al. (2025) suggested that students from families with higher socioeconomic status had better analytical skills because they had greater access to academic resources that supported the development of thinking skills. Moreover, international experience developed analytical thinking skills as students learned to deal with more complex and diverse problems (Basaran and Berberoglu, 2012; and Kim et al., 2025). Liu & Pásztor (2023) found that involvement in extracurricular activities oriented towards the development of critical thinking skills contributed to the improvement of students' analytical abilities. Therefore, curriculum design that incorporates extracurricular activities supporting analytical thinking skills can have a positive impact on students' cognitive development.

The findings of the study are largely consistent with previous research but also introduce several new insights that broaden the understanding of the relationship between demographic factors and analytical thinking skills. A key contribution of this research is the identification of the significant influence of involvement in extracurricular activities and international experience on analytical thinking skills, which has not been widely discussed in a broader context. The data indicate that age, GPA, university, and involvement in extracurricular activities have a significant influence on various dimensions of analytical thinking skills, such as classification, specification, and generalization. Furthermore, international experience also influences analytical thinking skills, especially in the ability to analyze errors.

Study Limitations

The study has several limitations that should be considered when interpreting the results and generalizing the findings. First, the sample was limited to students from several universities in Central Java, so the results cannot be generalized to the wider student population. Second, although the demographic variables tested were relatively broad, this study did not include other factors that may influence analytical thinking skills, such as psychological factors, learning styles, and the quality of teaching received by students. Third, while the study has considered several demographic factors, other aspects, such as socio-cultural background, have not been explored in depth and could be areas for further research.

Conclusions and Implications

Psychometric evaluation confirmed that the instrument to measure analytical thinking skills in the Zoology course met the standards of validity and reliability. The current study found that demographic factors, including age, GPA, university, education level, involvement in extracurricular activities, and international experience, influenced various dimensions of analytical thinking skills. Moreover, the findings suggest that GPA consistently influences almost all dimensions of analytical thinking, while international experience and involvement in extracurricular activities enhance error analysis and generalization skills. The factor structure of the developed instrument was determined through exploratory and confirmatory factor analysis. The results of the EFA indicated that the data were well suited for factor analysis, with a KMO value of .812 and significant Bartlett's Test of Sphericity results. Five main factors with eigenvalues greater than 1 were identified, explaining 75.33% of the total variance. The factors included (1) Matching, related to recognizing similarities and differences in attributes; (2) Classifying, which involves grouping items into appropriate categories; (3) Error analysis, which focuses on assessing errors in reasoning and procedural validity; (4) Generalizing, which reflects the ability to identify patterns and construct new generaliza-

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tions; and (5) Determining, related to applying generalizations or principles in specific situations. CFA supported the validity of this factor structure, with model fit indices indicating a good fit (χ^2/df = 2.34, RMSEA = .045, SRMR = .041, CFI = .956, TLI = .943, NFI = .925, GFI = .931, AGFI = .905). The results highlight the importance of international experience and extracurricular engagement in supporting the development of students' analytical thinking skills, which should be considered in higher education curriculum design. The implications of this study include the development of more valid and reliable instruments to assess students' analytical thinking ability, which can be used in further research and teaching practices in higher education. The contribution of the current study lies in providing a psychometrically tested instrument to assess analytical thinking skills in the context of science education, particularly in Zoology courses. Furthermore, the study extends the understanding of demographic factors that influence students' analytical thinking skills, particularly the role of international experience and extracurricular involvement, which have not been widely explored in the context of science education.

Declaration of Interest

The authors declare no competing interest.

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